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Automatic equalisation of temporary sound circuits for commentaries: subjective tests

No. 1971/41

Research Department, Engineering Division
THE BRITISH BROADCASTING CORPORATION

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AUTOMATIC EQUALISATION OF TEMPORARY SOUND CIRCUITS FOR COMMENTARIES: SUBJECTIVE TESTS

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AUTOMATIC EQUALISATION OF TEMPORARY SOUND CIRCUITS FOR COMMENTARIES: SUBJECTIVE TESTS

Summary

Temporary sound circuits in general have to be individually tested and the amplitude/frequency response equalised before use; they thus make considerable demands on man power, and it would be an advantage if this routine work could be carried out automatically.

The complexity of an automatic system for amplitude/frequency response equalisation is related to the tolerance limits applied to the circuit performance. It is therefore important when considering automatic equalisation to determine the tolerances that are necessary, having regard to the purpose for which the circuit is required.

For some classes of programme, such as commentaries on sporting events (which constitute a major application of temporary circuits), some relaxation of normal broadcasting standards may be permitted without serious impairment of the programme. It is therefore possible that an equaliser of simple basic form, such as might be automated without undue difficulty, could give satisfactory results for the majority of such applications.

This report describes subjective tests carried out to determine the frequency range necessary for circuits used to carry commentaries, and, within that frequency range, the tolerances in the response characteristics which may be permitted.

1. Introduction

Sound programme circuits may be divided into two groups under the heading 'permanent' or 'temporary' according to the way in which they are used. Permanent circuits are held by a broadcasting organisation for regular use, as, for example, in a programme distribution network; they are required, therefore, to carry all types of programme. Temporary circuits, on the other hand, are commonly used for contributions from outside broadcast points, and, in this case, each is generally required to carry only one type of programme.

To avoid unacceptable impairment of the reproduced programme the amplitude/frequency response characteristics of all sound circuits, permanent and temporary, must lie within appropriate tolerance limits, and, where necessary, equalisation must be introduced to achieve this end. Temporary circuits, each of which has normally to be tested and equalised individually before use, at present make considerable demands on man-power. In some circumstances the processes of testing and equalisation could be carried out automatically, with consequent reduction in the burden of routine work required to be carried out manually.

The complexity of an amplitude/frequency response equaliser is related to the overall tolerances of response characteristic which are allowed for the circuit concerned; it is important therefore to establish working tolerance limits which are no more stringent than the situation demands. The standards appropriate for temporary circuits depend, to some extent, on the nature of the programme for which the circuit is required; performance unacceptable for an orchestral concert could well be adequate for, say, a commentary on a sporting event. A large proportion of temporary sound circuits are, in fact, used for commentaries, and it is therefore worthwhile considering automatic equalisation for this application. Some relaxation of normal broadcasting standards for amplitude/frequency response characteristics is already accepted for commentaries, a maximum spread of 3 dB being allowed over a minimum frequency range of 50 Hz to 6 kHz. Examination of test data for some 150 temporary circuits indicates that the above tolerance limits could be met in about 87% of cases by a simple, single-stage, equaliser using only one CR circuit. It is possible that the above standards are still unnecessarily stringent for the purpose being considered, and that the simple equaliser might, in fact, give results acceptable in practically every case.

This report describes subjective tests carried out to see how far the existing tolerance limits of amplitude-frequency response characteristic could be relaxed on circuits used for commentaries only. Most of the investigation was carried out using a wide-range reproducing system, but some tests were also included in which the effect of listening on a representative m.f. receiver was simulated.

2. Forms of amplitude/frequency response characteristics explored

The investigations were divided into two parts; in the first, tests were carried out to determine subjectively the restriction of bandwidth, at both low and high frequencies, acceptable for commentary circuits. Low-frequency band restriction was introduced by including in a reproducing circuit a continuously variable filter giving an ultimate cut-off rate of 24 dB per octave, while high-frequency band restriction was provided by switching into circuit one of four, fixed, low-pass filters. Fig. 1 shows the amplitude/frequency response characteristics of the fixed low-pass filters, and of the variable high-pass filter when set to a nominal cut-off frequency of 95 Hz. Throughout this report the filters will be identified by the frequency at which the insertion loss is 3 dB greater than at mid band.

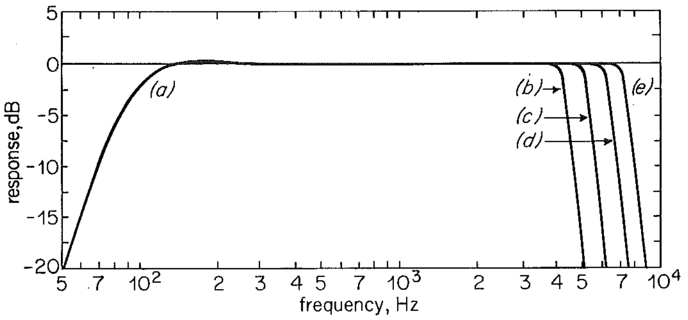

Fig. 1 - Amplitude/frequency response characteristics of filters used to restrict frequency range

(a) Variable high-pass filter : example shows nominal cut-off at 95 Hz
(b) Fixed low-pass filter : nominal cut-off 4·3 kHz
(c) Fixed low-pass filter : nominal cut-off 5·3 kHz
(d) Fixed low-pass filter : nominal cut-off 6·3 kHz
(e) Fixed low-pass filter : nominal cut-off 7·3 kHz
Loss at nominal cut-off frequency : 3 dB relative to loss at mid band

The second part of the investigation was planned to provide data on the permissible tolerance limits of response deviation within the bandwidth determined by the first group of tests. It was obviously impracticable to consider all possible variations of response characteristics; the present subjective investigation was therefore arranged, in the main, to determine the permissible deviations of response at the extremes of the frequency range determined in the first part of the investigation. The response characteristics of the test circuits used are shown in Fig. 2. It was arranged that these circuits could be introduced individually, or in combination — as, for example, bass loss combined with top lift. When used in combination the circuits were set so that the deviations of response were equal at the nominal upper and lower limits of the frequency band.

Tests were also carried out with a family of characteristics, shown in Fig. 3, having a response maximum at about 2½ kHz; these characteristics were based on a preliminary study of the equalisation of temporary circuits and have the general form of the residual error commonly obtained when the equalisation is provided by one possible simple circuit arrangement.

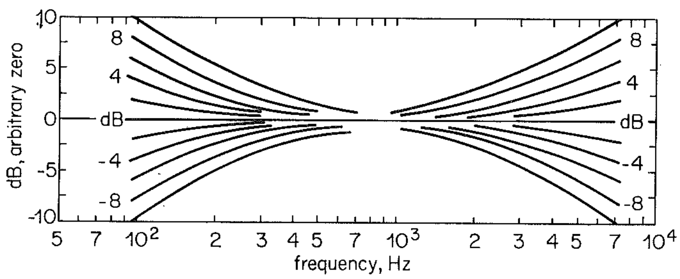

Fig. 2 - Amplitude/frequency response characteristics of test circuits affecting high and low frequency ranges. Deviation in response at 95 Hz and 7·3 kHz varied in 2 dB steps.

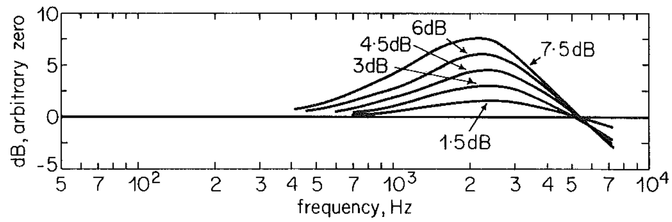

Fig. 3 - Amplitude/frequency response characteristics of test circuits affecting 2·5 kHz region. Deviation in response at 2·5 kHz varied in 1·5 dB steps.

3. Programme material used for subjective tests

The test programme for the investigation was recorded at Outside Broadcast points during a number of sports events. In all, twelve voices were recorded; these, with one exception, were male. As no more commentaries by female voices were available at the time, an additional recording of a female voice reading a test passage was included for some tests; the observers, however, were always instructed to judge the quality of the speech as if it were a commentary.

For the first group of tests — those to determine the necessary channel bandwidth — the voices of all the commentators were used. It was impracticable, however, to investigate, with each voice, all the forms and degrees of response deviation considered in the second group of tests. For this reason a preliminary selection was carried out, using three of the more experienced observers, to choose the most critical voice for each form of response variation.

In the course of these preliminary tests it was found that the subjective tolerance to bass loss and top loss combined, or to bass lift and top lift combined, was no more stringent than for bass loss, top loss, bass lift, or top lift, taken individually. These combinations were therefore not included in further tests.

4. Test conditions

The subjective tests were carried out in a listening room having a volume of 85 cubic metres and a mean mid-band reverberation time of about 0·3 seconds. The test programme was reproduced over a wide-range loudspeaker, type LS5/5, at a maximum sound level of approximately

74 dBA. As indicated in Section 1, the full frequency range of the reproducing system was used for most of the investigation; a few tests were also carried out, however, with the characteristics of the reproducing system modified to simulate the overall amplitude/frequency response of a representative m.f. receiver.[1]

The observers took part one at a time in the experiment to determine the necessary circuit bandwidth, and in groups for the investigation into the permissible tolerances of amplitude-frequency response.

5. Observers

All the observers taking part in the experiment were BBC technical staff; most had some experience — and a few, very wide experience — in assessing the quality of sound programmes. The number taking part in the investigations was not constant, but is indicated for each test in the appropriate section.

6. Subjective tests*

6.1 Determination of channel bandwidth required for sports commentaries

6.1.1 General

Ten observers, one at a time, took part in this investigation.

* Much of the copying and editing of the recorded excerpts used in the investigations was carried out by G.C. Wilkinson who also conducted many of the subjective tests.

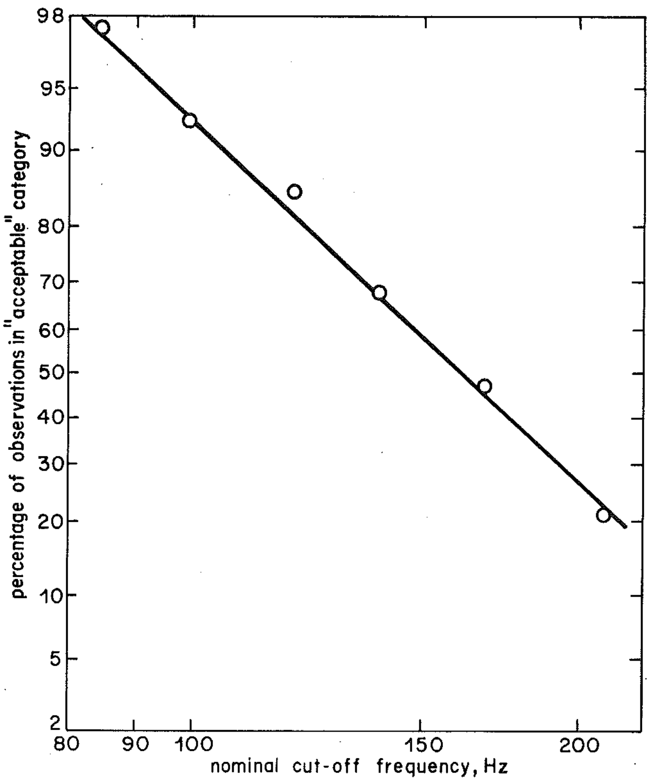

Fig. 4 - Subjective effect of altering low-frequency band restriction on commentaries.

Each observer was asked, for each commentator's voice, to reduce circuit bandwidth, simultaneously at high frequencies and at low frequencies, as far as possible while still leaving the programme acceptable as a commentary. The settings of the band restriction filters were then noted.

6.1.2 Results

The results plotted in Figs. 4 and 5 show the percentage of observations in the 'acceptable' category, plotted as a function of low-frequency and high-frequency band restriction respectively. It will be seen that low-frequency band restriction at about 95 Hz and high-frequency band restriction at about 7·3 kHz, each give approximately 95% 'acceptable' observations. This performance was regarded as satisfactory and it is suggested that in an automatic equaliser system used for commentaries only, the audio frequency bandwidth could well be restricted to the range 95 Hz to 7·3 kHz.

6.2 Determination of acceptable deviation of response characteristic for commentary circuits restricted to 95 Hz to 7·3 kHz bandwidth

6.2.1 General

Test excerpts, of approximately 20 second duration and arranged in arbitrary order, were prepared for all the various forms and degrees of response variation to be examined, using, in each case, the appropriate voice selected as indicated in Section 3. In general the frequency range

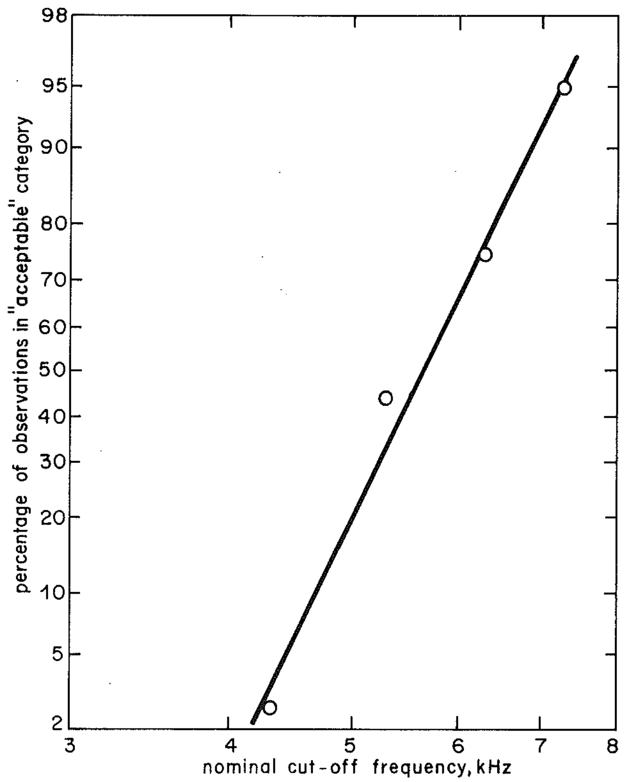

Fig. 5 - Subjective effect of altering high-frequency band restriction on commentaries.

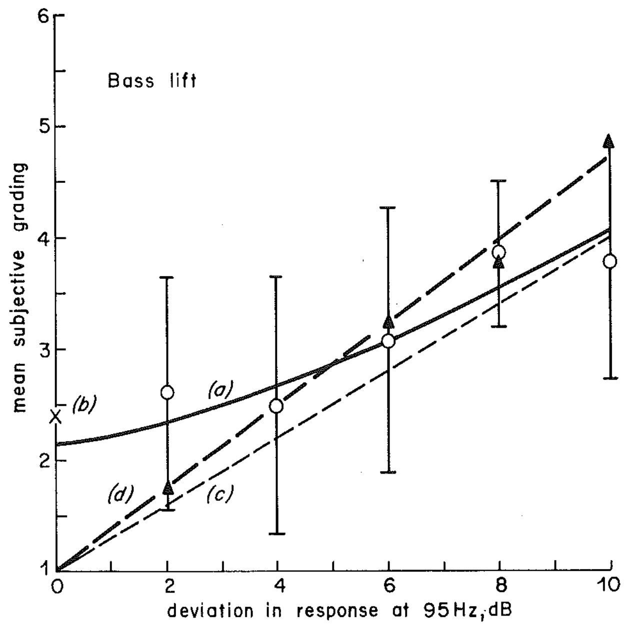

Fig. 6 - Subjective effects of altering system response at low frequencies

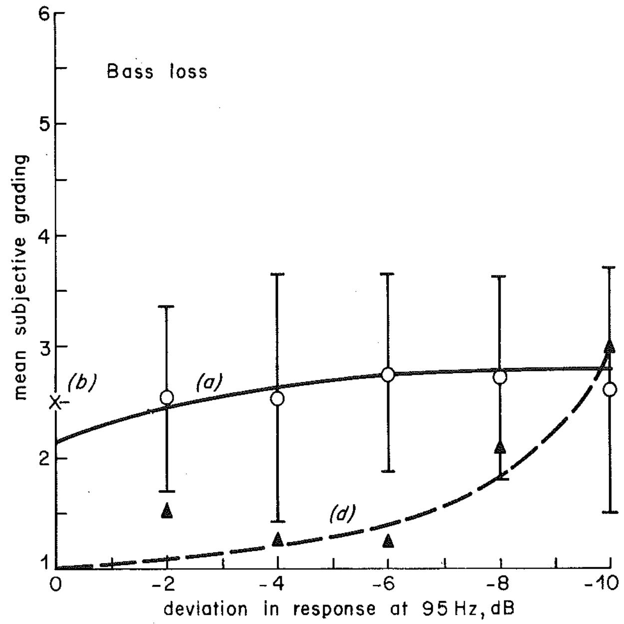

Fig. 7 - Subjective effects of altering system response at low frequencies

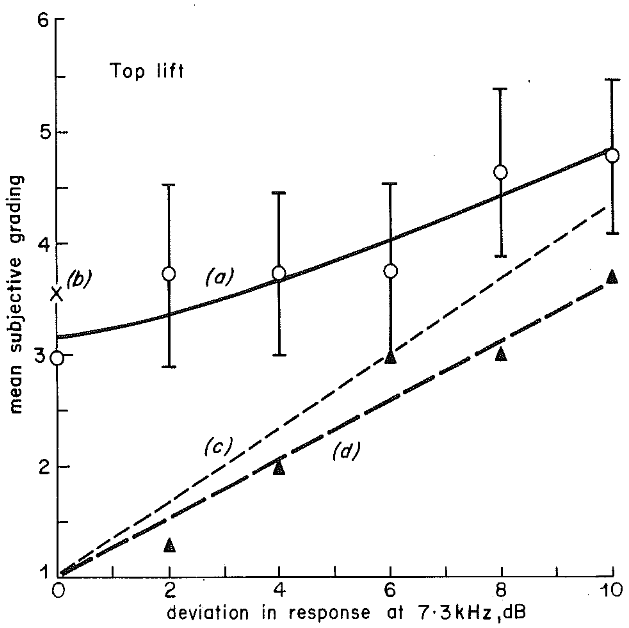

Fig. 8 - Subjective effects of altering system response at high frequencies

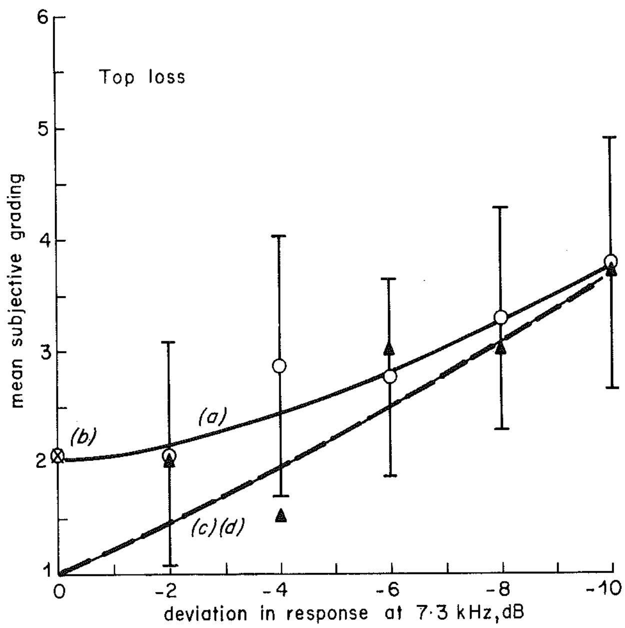

Fig. 9 - Subjective effects of altering system response at high frequencies

for each test passage was restricted to a 95 Hz to 7·3 kHz band, but, for each voice used in the tests, an excerpt giving full-range reproduction was also included.

Fourteen observers, in groups, took part; they were asked to judge the acceptability of the programme as a commentary, and to grade each excerpt on the following scale:—

Grade	Impairment
1	Imperceptible
2	Just perceptible
3	Definitely perceptible but not disturbing
4	Somewhat objectionable
5	Definitely objectionable
6	Unusable

These tests will be referred to as the 'absolute grading tests' to distinguish them from others, to be described later, in which standards of reference were included in the presentation.

6.2.2 Results

The results are presented in Figs. 6 to 11 curves (a) which show the mean subjective grade plotted against the amount of deviation in circuit response at 95 Hz or 7·3 kHz, as appropriate, together with the standard deviations of the observations for each point plotted. Fig. 12 shows the corresponding data for the circuit giving a response maximum at about 2½ kHz. The mean grading

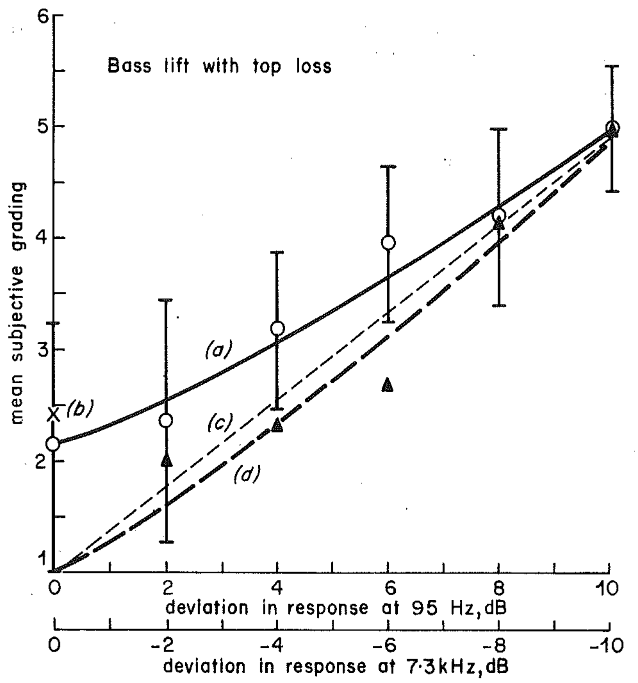

Fig. 10 - Subjective effects of altering system response at both high and low frequencies

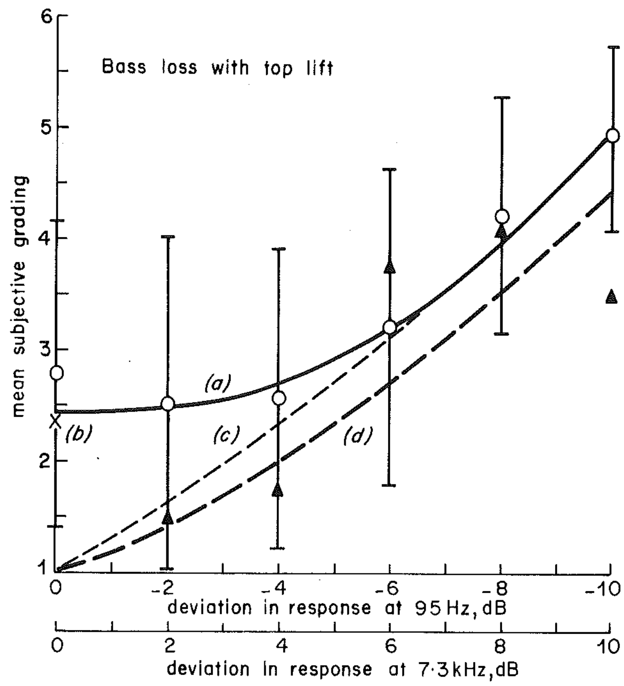

Fig. 11 - Subjective effects of altering system response at both high and low frequencies

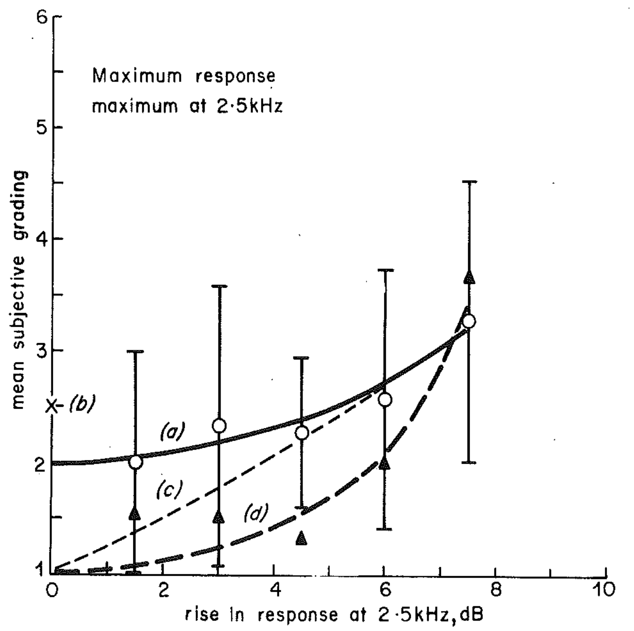

Fig. 12 - Subjective effect of altering system response in 2·5 kHz region

Key to Figs. 6-12

(a)	o———	Data from absolute grading tests
(b)	x	Data from full-frequency-range presentation (absolute grading)
(c)	- - - - -	Estimated curve passing through origin
(d)	▲———	Data from relative grading tests
	Ɨ	± 1 standard deviation of observations

of the full-frequency-range presentation of the appropriate voice is also included, point (b), in each case. The latter points are, in every case, within about ½ grade of the corresponding figure obtained with uniform response over the restricted frequency range 95 Hz to 7·3 kHz, and are frequently of worse grading. These results indicate that the band restriction introduced has had little adverse effect, and that in some cases may be actually beneficial.

Interpretation of curve (a), Figs. 6 to 12, is in all cases difficult, as the line drawn through the points plotted does not pass through the origin, i.e. the observers judged the unimpaired programme as less than perfect. This situation may be explained in part by over-anxiety on the part of the observers, and in part by imperfections in the original test material. An indication of the results to be expected in the region of low impairment in the absence of such effects can be obtained in most instances by estimating the position of a new curve which passes through the origin and will eventually meet the original curve in the region of high impairment. Curves derived in this manner are shown in Fig. 6*(c)* and Figs. 8*(c)* to 12*(c)*.

6.2.3 Supplementary tests

In the case of Fig. 7, the original data, curve (a), is substantially independent of the amount of deviation in response introduced — suggesting a relatively high degree of tolerance to bass loss — and it was not possible to estimate the position of a curve passing through the origin. Supplementary tests were therefore carried out* to obtain data from which tolerance limits for bass loss could be derived. These tests were carried out using only 4 observers (in a few cases only 3), selected because of the consistency of their results in the earlier investigation.

Each test consisted of the appropriate programme item, reproduced, first through the system with uniform response over the range 95 Hz to 7·3 kHz, then through the system with the appropriate response characteristic added. The observers were instructed to regard the first presentation as Grade 1, and were asked to grade the second presentation on the six-point scale given in Section 6.2.1, again judging the programme on its acceptability as a commentary.

These tests will be referred to as the 'relative grading tests' to distinguish them from the 'absolute grading tests' described in Sections 6.2.1 and 6.2.2.

To gain an indication of the degree of confidence in the results obtained in the supplementary tests, these were carried out, not only for bass loss, but also for the other forms of response deviation examined in the earlier tests. In view of the apparent tolerance of bass loss suggested by Fig. *7(a)* it was decided further to include in the supplementary tests a combination of characteristics in which the amount of bass loss introduced was twice that of the top lift.

* Using a method proposed by E.R. Rout

The investigation was carried out in a number of test sessions; exploration of each form of response variation was completed in one test session, but within the session the degree of response variation was changed in an arbitrary way.

6.2.4 Results of supplementary tests

The results of the supplementary tests are shown in Figs. 6 to 13, curve (d); mean subjective grade is again plotted against the deviation of the curcuit response in dB. It will be seen that in most cases the agreement with the "estimated curve" derived from the absolute grading tests — Fig. 6(*c*) and Figs. 8(*c*) to 12(*c*) — is reasonably good; for test conditions giving mean gradings around 2, for example, the difference between the two curves is generally within ¼ grade. This degree of agreement suggests that for bass loss, where it was not possible from the results of the absolute grading tests, Fig. 7(*a*), to estimate the position of a curve passing through the origin, permissible tolerance limits can reasonably be derived from the relative grading tests, Fig. 7(*d*).

7. Interpretation of results

From Figs. 6 to 13, curves (c) and (d) it may be estimated that, if, for example, a mean subjective grade of 2 is taken as reference, the deviation in response of a sound circuit having 95 Hz to 7·3 kHz bandwidth, used for a commentary, should not exceed the following limits:—

Deviation in response at frequency indicated, dB.

		Absolute grading tests			Relative grading tests		
		95 Hz	2·5 kHz	7·3 kHz	95 Hz	2·5 kHz	7·3 kHz
Fig. 6	Bass lift	+ 3¼ dB			+ 2¾ dB		
Fig. 7	Bass loss				– 8½ dB		
Fig. 8	Top lift			+ 3dB			+ 3¾ dB
Fig. 9	Top loss			– 4¼ dB			– 4¼ dB
Fig. 10	Bass lift with top loss	+ 2½ dB		– 2½ dB	+ 3¼ dB		– 3¼ dB
Fig. 11	Bass loss with top lift	– 3 dB		+ 3 dB	– 4 dB		+ 4 dB
Fig. 12	Max lift at 2½ kHz		4 dB			6 dB	
Fig. 13	Bass loss with top lift				– 5 dB		+ 2½ dB

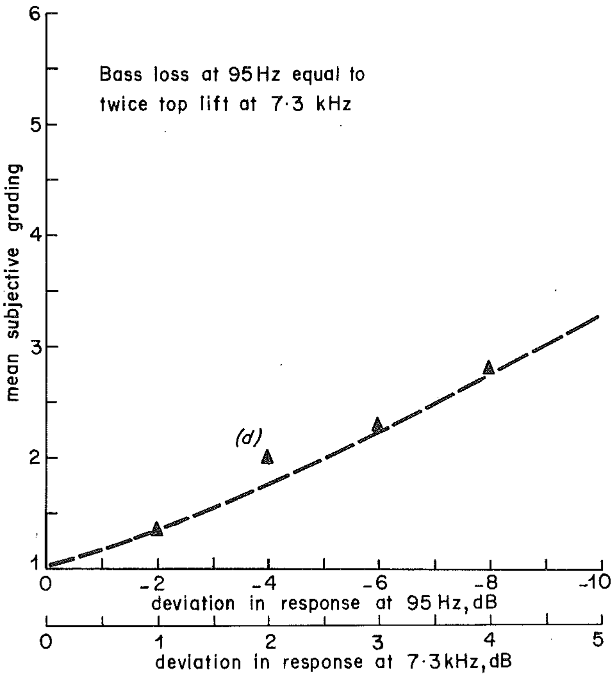

Fig. 13 - Subjective effect of altering system response at both high and low frequencies

(d) ▲ — — — Data from relative grading tests.

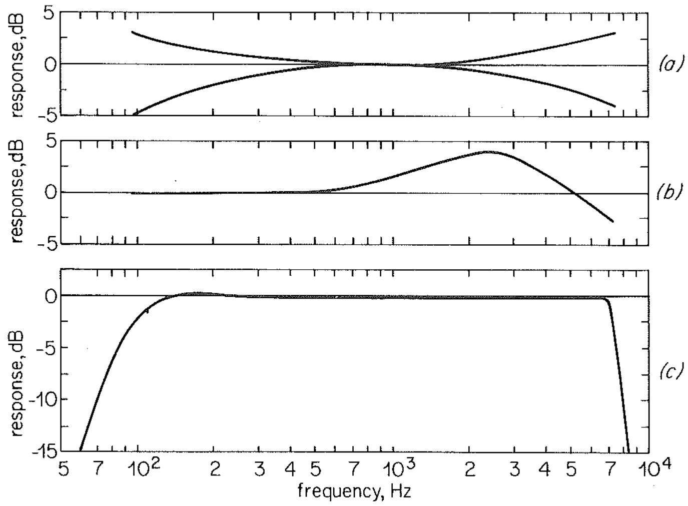

Fig. 14 - Estimated limits of amplitude/frequency response giving subjective grade 2 or better

(a) Deviations in response at ends of frequency band
(b) Deviations in response in 2·5 kHz region
(c) Overall band restriction applied to response (additional to (a) and (b)).

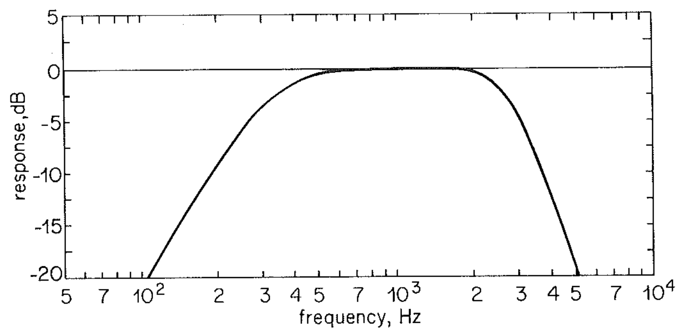

Fig. 15 - Amplitude/frequency response characteristic of network used to simulate m.f. reception conditions

It must be remembered that the results given above were obtained using, for each form of response deviation, the most searching test material available. For the majority of voices therefore, the response characteristics indicated above should result in a mean grading better than grade 2. It is accordingly suggested that the following limits in response should, in practice, generally give results of grade 2 or better, when used on commentary circuits restricted to a 95 Hz to 7·3 kHz bandwidth: response at 95 Hz, +3 dB to −5 dB, response at 7·3 kHz, +3 dB to −4 dB; where, as shown in Fig. 3, response takes the form of a maximum at about 2·5 kHz (falling at frequencies above 5 kHz), the level at 2·5 kHz should not rise more than 4 dB. The curves showing these limits of deviation of response are given in Fig. 14.

Assuming that the standard deviations of the observations indicated in Figs. 6*(a)* to 12*(a)* can also be applied to the estimated curves Figs. 6*(c)* to 12*(c)*, the limits of response deviation given above could result, in the worst case, in up to 15% of the observations being grade 3½ or higher; in most cases, however, this percentage should be much less.

8. Effect of simulated medium-frequency reception conditions

If the bandwidth of the communications system over which a commentary is being received is itself severely restricted — as for example by the i.f. and loudspeaker response characteristics of a m.f. receiver — then it might be expected that additional response variation up to the limits suggested in Section 7 would have negligible effect.

It was considered just possible, however, that even a slight additional degradation in characteristic might prove unacceptable when superimposed on the receiver response characteristics; a further subjective investigation, again using the few selected observers, was therefore carried out to check the effect of narrow-band reception conditions. For these tests, a network simulating the response obtained with a representative m.f. receiver,[1] and having the characteristic given in Fig. 15 was permanently included in the reproducing chain. Each test comprised two presentations, in random order, of a test item; in one presentation the programme was applied to the narrow-band reproducing chain through a circuit having an amplitude/frequency characteristic nominally flat from 95 Hz to 7·3 kHz, while in the other, one of the various forms and degrees of response variation, described in Section 2, was added. The observers were asked to grade the second presentation, (B), of each test pair as better than, or worse than, the first presentation, (A), on the following scale:

B much better than A	Grade 3
B better than A	Grade 2
B slightly better than A	Grade 1
B the same as or equal to A	Grade 0
B slightly worse than A	Grade −1
B worse than A	Grade −2
B much worse than A	Grade −3

In these tests, changing the amplitude/frequency response characteristics by amounts up to the limits suggested in Section 7 at no time caused the mean grading of the two presentations to differ by more than ¾ grade. This result was obtained under test conditions in which direct comparison was allowed, and indicates that, under normal m.f. listening conditions, the quality of broadcast commentaries would be substantially unaffected by deviations in response within the limits suggested.

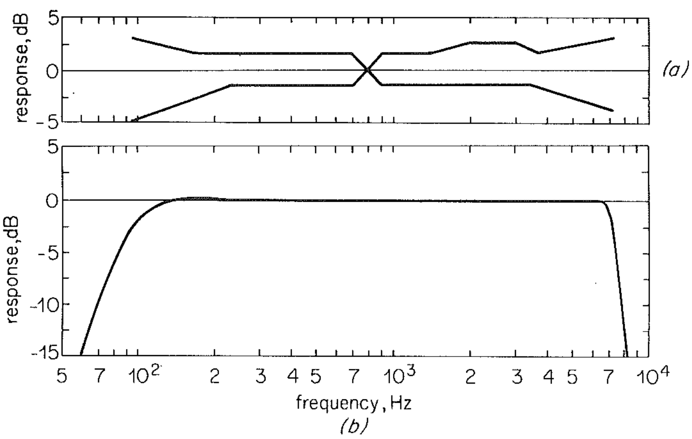

Fig. 16 - Suggested working tolerance limits for amplitude/frequency response of circuits used for commentaries

(a) Limits of response deviation : composite curve
(b) Overall band restriction applied to response (additional to (a)).

9. Suggested working tolerance limits

Fig. 14, derived from the present tests, indicates limits which, it is estimated, should result, for most voices, in a mean subjective grading of 2 ('Impairment Just Perceptible') or better, when applied to commentary circuits restricted to a frequency range of 95 Hz to 7·3 kHz. If it is assumed that the existing tolerance for commentary circuits – 3 dB spread in response – may be applied to the mid-band region, then the composite limits shown in Fig. 16 are obtained. Here the curves have been normalised at 800 Hz and include suggested relaxations of tolerance at the ends of the frequency range and in the 2 kHz to 3 kHz region. It is accepted that some response characteristics of unusual form may give a mean grading worse than 2, while still falling within the composite limits given in Fig. 16; it is considered, however, that these limits represent working tolerances which, in the vast majority of cases, will give satisfactory results.

10. Effect of relaxed tolerance limits

The benefits of relaxation of tolerance limits lie in the increased percentage of occasions on which an equaliser of given configuration can be shown to provide acceptable results. If the suggested frequency range of 95 Hz to 7·3 kHz were adopted for commentary circuits, and the existing tolerance limit – i.e. a 3 dB spread in response within the band 50 Hz to 6 kHz – were replaced by the limits indicated in Fig. 16, the percentage of the temporary sound circuits considered which could be equalised within tolerance by a simple CR equaliser would rise from 87% to about 96%. This confirms that an equaliser of very simple basic form is indeed likely to give satisfactory equalisation of the vast majority of the temporary sound circuits used for commentaries.

11. Conclusions

Subjective tests have been carried out to determine the necessary circuit bandwidth and, within that bandwidth, the tolerance limits for amplitude/frequency response characteristic appropriate for temporary sound circuits used for commentaries only.

It is concluded that the present lower-frequency limit of 50 Hz could be raised to 95 Hz, but that, where possible, the upper-frequency limit should not be below about 7·3 kHz; further, the present tolerance limits for response could be considerably relaxed at the high- and low-frequency ends of the 95 Hz to 7·3 kHz band. It has been confirmed by subjective tests that the limits suggested above for wide-range listening conditions are also acceptable when the frequency range is restricted, as it might be, for example, by a m.f. receiver.

Implementation of the revised tolerance limits suggested would raise the success rate for a very simple basic form of equaliser, such as might lend itself readily to automation, from some 87% to about 96%.

The work described in this report was carried out primarily to determine the standards appropriate for an automatic equaliser system; the results, however, apply equally to manual equalisation.

12. References

1. Frequency response characteristics of four a.m. receivers. BBC Research Department Report No. 1969/34.

DC/JUC

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